UNITED STATES DEPARTMENT OF AGRICULTURE, FOREST SERVICE

PROGRESS REPORT

A FIELD EXPERIMENT IN DETERMINING THE EFFECTIVENESS OF FLUORESCENT TRACER RHODAMINE FOR ASSESSING SPRAY DEPOSIT OF REGISTERED ZECTRAN FORMULATION (NEZPERCE NATIONAL FOREST, IDAHO, 1971)

by

Bohdan Maksymiuk, John Neisess, Richard A. Waite, and Richard D. Orchard
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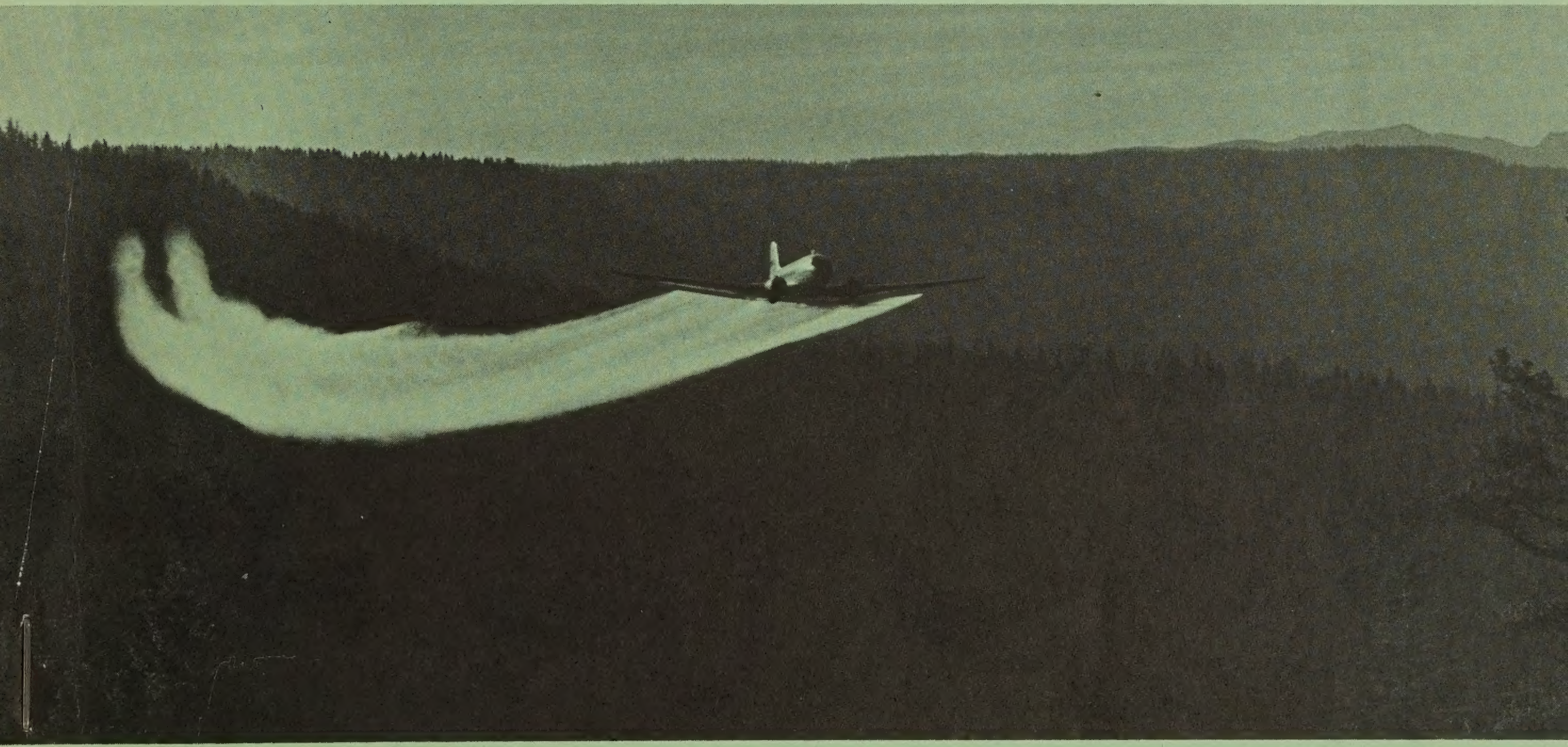

Pacific Northwest Forest and Range Experiment Station
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ACKNOWLEDGMENTS

The authors gratefully acknowledge the cooperation received from Fredrick W. Honing, William M. Ciesla, Jerald E. Dewey, and others in Region 1, especially for collecting samples of foliage for spray deposit analyses and for sharing the spruce budworm mortality data for investigating the correlation between the amount of spray deposit and the degree of spruce budworm mortality. This field experiment would not have been possible without this cooperation.

Appreciation is expressed to Tony Jasumback and others from the Missoula Equipment Development Center for assistance in spray mixing, and to Dr. Robert L. Lyon for confirming that the fluorescent tracer Rhodamine had no effect on the toxicity of Zectran formulation to the spruce budworm larvae. Thanks are also due Kenneth H. Wright, David E. Ketcham, Dr. William E. Waters, and others for their help, interest, and suggestions in planning and execution of this effort. The cover photograph is the courtesy of Louise J. Parker of the Pacific Southwest Forest and Range Experiment Station.

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SUMMARY

This field experiment was conducted cooperatively with Region 1 in conjunction with the Zectran pilot control study. The main purpose was to determine the effectiveness of Rhodamine fluorescent dye for spray deposit assessment under operational field conditions. Registered Zectran formulation, containing 0.1 percent tracer, was applied at the rate of 1.0 gallon per acre by two C-47 aircraft.

Results of this experiment show that satisfactory techniques have been developed in the laboratory and successfully field tested for qualitative and quantitative spray deposit assessment. Refinements and improvements are needed.

There was a high variation in spray deposit within and between tree canopies and at the ground level at different locations throughout the spray block. A high correlation of spray deposit and spruce budworm mortality was obtained when deposit data were grouped into several classes. There was a low correlation using individual tree data.

Continued efforts are needed to improve both the qualitative and quantitative procedures for assessing spray deposit using fluorescent tracer techniques.

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INTRODUCTION

Reliable, rapid, and economic spray deposit assessment methods are needed for improving aerial application technology and for the operational uses of pesticides. Assessment of deposit is also needed for the enforcement of spray contracts. A deposit assessment technique is a research tool for obtaining basic knowledge which will eventually lead to increased insect mortality without necessarily increased dose and to reduced drift.

The adequacy of spray coverage of aerial applications of insecticides has commonly been checked by sampling the spray deposit at the ground level using oil-sensitive cards (Davis and Elliott, 1953). However, such assessment methods have been shown to be unrealiable for obtaining a satisfactory correlation between the deposit and the insect mortality (Maksymiuk, 1963b). Davis et al. (1956) sampled spray deposit at midcrown on four sides of the trees by using aluminum plates. The spray formulation contained DuPont oil red dye. The spray deposit was determined by chemical or colorimetric

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1/ Project Leader, Chemist, Physical Science Technician, and Biological Laboratory Technician, respectively.

methods. This assessment method provided a good correlation between deposit and insect mortality, thus furnishing a reliable measure of the efficiency of the various treatments tested.

A fluorescent particle tracer technique was developed in the late 1940's. It has been employed as an atmospheric air tracer for use in both the U.S. Army Chemical Corps and air pollution investigations. The fluorescent particles were used successfully by the U.S. Forest Service to determine the size and number of aerial drops impinging on the spruce budworm in its natural habitat (Himel et al., 1965; Himel and Moore, 1967).

Although the dye tracer and fluorescent particle techniques have been used for experimental field tests, they have certain disadvantages. The dye technique requires considerable time and personnel to handle the sampling procedures, and the dyes are subject to fading (Isler, 1962). Also, the dye deposit assessment involves a colorimetric analytical procedure which is not sensitive enough to detect drift. The high cost and operational difficulties (Honing, 1968) of the fluorescent particles would seem to limit their usefulness as a deposit assessment method to experimental use only. Therefore, development of a more desirable tracer system was needed for evaluating spray deposit.

Following meetings with Forest Pest Control representatives from the Washington Office and Region 1 in Corvallis, intensive laboratory research was initiated for the development of qualitative and quantitative spray deposit assessment methods for the registered Zectran formulation using a soluble fluorescent tracer. The criteria for selecting a suitable fluorescent tracer(s) were established, then

using these criteria, the most promising fluorescent tracers were screened and evaluated. Rhodamine B Extra Base appeared to be the most satisfactory fluorescent dye tracer. Based on routine laboratory bioassays, Rhodamine, at the field concentration (0.1 grams per 100 ml), showed no detectable effect on the toxicity of the registered Zectran formulation to the western spruce budworm larvae, *Choristoneura occidentalis* Freeman (Appendix A).

OBJECTIVES

The main objective of the field experiment was to evaluate the effectiveness of Rhodamine B Extra Base, fluorescent tracer, for assessing the spray deposit under field conditions. The specific objectives were as follows:

1. Qualitative deposit assessment.--To test a rapid and simple qualitative method for determining the forest coverage immediately after spraying to detect omissions or low deposit for possible respraying.

2. Quantitative deposit assessment.--To test the accuracy and precision of developed quantitative analytical methods for determining spray deposit directly on the target (foliage) and non-target areas (drift).

3. Correlation of deposit and mortality.--To determine the optimum sample size and standardize analytical techniques for the correlation of the quantity of spray deposit and the degree of spruce budworm mortality.

MATERIALS AND METHODS

Area.--The spray test block (Service Flats) was located in the Nezperce National Forest, east of Grangeville, Idaho. This spray block contained about 2,100 acres of mainly second growth Douglas-fir and grand fir trees. The elevation ranged approximately from 4,200 to 5,100 feet, and the terrain was fairly representative of the control blocks.

Design.--The field experiment was conducted in conjunction with the pilot control study using registered Zectran formulation against the spruce budworm *Choristoneura occidentalis* Freeman. The Service Flats spray block was one of the three original spray areas for the pilot test. Three additional areas of about the same acreage as the treatment blocks were used as untreated controls to determine the natural larval mortality. Each treated area was paired with one untreated control.

The aerial application procedure was the same for all three spray blocks. The formulation containing 0.15 pounds of Zectran per gallon was applied at the rate of one gallon per acre.

The total of 100 trees (50 grand fir and 50 Douglas-fir) were established before spraying in the "Rhodamine block" as in the other control blocks (fig. 1). These trees were sampled for larval mortalities and, in the case of the "Rhodamine block", also for the spray deposit.

Insect Sampling.--All spruce budworm population assessments were conducted by personnel from Region 1. The test blocks were sprayed when 90 percent of the larvae were in the fourth and fifth instars. A detailed report of the insect population and sampling procedures will be reported by Region 1.

Equipment.--The two aircraft, C-47, and spraying equipment were provided by Region 1. The spray equipment included 102, 8015 T-Jet flat fan nozzles (Spraying Systems Company)[2/]. The nozzle orifices were directed downward 90° to the thrust line of the aircraft, and the spray pressure was 40 psi. The spraying speed of the aircraft was 150 mph.

Formulation.--The spray formulation used for the field experiment included the same registered Zectran formulation (0.15 lb. Zectran/gal.), that was used for the other two spray blocks, with the addition of 3.78 gr. (0.1% w/v) of Rhodamine B Extra Base (General Aniline and Film Corp.)[2/] per gallon of spray. The carrier was 10 percent Dowanol TPM (solvent that Zectran was shipped in) and 90 percent Chevron Base Oil "C".

Samples of the complete formulation were collected prior to spraying to determine the initial concentration of the fluorescent tracer.

2/ Mention of the name of the manufacturer or a product does not constitute endorsement by the U.S. Department of Agriculture.

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Spray Application.--The spray blocks were sprayed in about the same manner. The planes sprayed in an approximate east to west direction. The swath spacings were an estimated 500 feet apart. The spraying height was about 300-500 feet above the tree tops, depending on the variation in the topography. The two aircraft applied the spray in successive swaths using the spray cloud of the preceeding plane's flight as a guide for the swath spacings. The addition of the fluorescent tracer to the spray formulation increased the visibility of the spray swaths.

Spray Atomization.--To determine the spray atomization under the forest condition, thirty white Kromekote paper cards fastened to aluminum plates were placed in the spray block. The cards were set on card holders (Maksymiuk, 1959) along a 600-foot section of the road that transversed the spray plot. The cards were spaced at 20-foot intervals on a portion of the road that was perpendicular to the line of flight of the aircraft.

The cards were collected five hours after spraying and transported to the Forestry Sciences Laboratory, Corvallis, Oregon, for the determination of the spray atomization. The spray atomization was determined by the drop size spectra method (Maksymiuk, 1964).

Spray Deposit Assessment.--Foliage samples, aluminum plates (6" x 6"), and white Kromekote cards (4" x 5") were used for the qualitative and quantitative spray deposit assessments (fig. 2). The foliage samples were collected immediately after spraying (within 3 hours) from the same 96 trees that were sampled for larval

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mortalities. Four, 10-inch twig samples were cut at mid-crown from each tree. The samples were taken from the four cardinal directions of each tree, and placed in brown paper bags. The tree number, sample direction (north, east, south, west) and collection time were recorded on each bag. The bagged foliage samples were transported to the Corvallis laboratory for spray deposit analysis.

The aluminum plates were used to sample the spray deposited at the ground level. Two aluminum plates were placed under 12 extra sample trees to determine the deposit that filtered through the tree canopies. The two plates were placed about five feet apart on the opposite sides of each tree trunk (fig. 2). Two other aluminum plates were positioned in the nearest open area adjacent to each tree. These plates were used to determine the amount of spray reaching the ground level in the open compared to the spray reaching the ground level under the tree canopy. White cards fastened to aluminum plates were also placed under the trees and in the open for visual estimates of the spray deposit. After spraying, the aluminum plates and aluminum plates with the white cards were placed in slotted boxes and transported to the laboratory.

White cards attached to aluminum plates were also placed along the main road that transversed the spray block (fig. 1). The cards were placed at 0.1 mile intervals for the determination of spray deposit reaching the ground level throughout the test area.

The qualitative and quantitative analysis of the spray deposit was conducted in the laboratory. The amount of spray on the various sampling surfaces was determined by fluorometric analysis similar to that reported by Yates and Akesson (1963). The detailed analytical

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procedures will be reported elsewhere. The initial concentration of the fluorescent tracer in the spray was determined from the three spray samples that had been collected just prior to the spray application.

For the foliage samples, two 75 needle subsamples were selected at random from each twig. The spray deposit was eluted from the needles by washing them 20 minutes in 10 ml of a 30 percent aqueous ethanol solution. The concentration of the fluorescent tracer was measured with a Turner Spectrofluorometer, Model 430. The emission and excitation wavelengths were set at 600 and 530 nanometers, respectively.

The amount of the spray on the aluminum plates was determined by a fluorometric method similar to that used for the foliage. However, in this case, the deposit was eluted with 10 ml of 95 percent ethanol. The number of spray drops per unit area on the white cards were also counted and compared with the concentration of spray on the corresponding aluminum plate. The drops were counted on four square centimeters in a darkroom under a dissecting microscope using an ultraviolet light for illumination of the fluorescent deposit.

Correlation of deposit and budworm mortality.--For the analysis of the correlation of spray deposit and insect mortality, the deposit data (μg Zectran/75 needles) were converted to logarithms, and the percent mortalities were transformed to probits. The correlation was investigated using individual tree and grouped data. The regression lines for the various relationships between deposit and mortality were computed by the least squares method. All regressions were tested for significance by using analysis of variance.

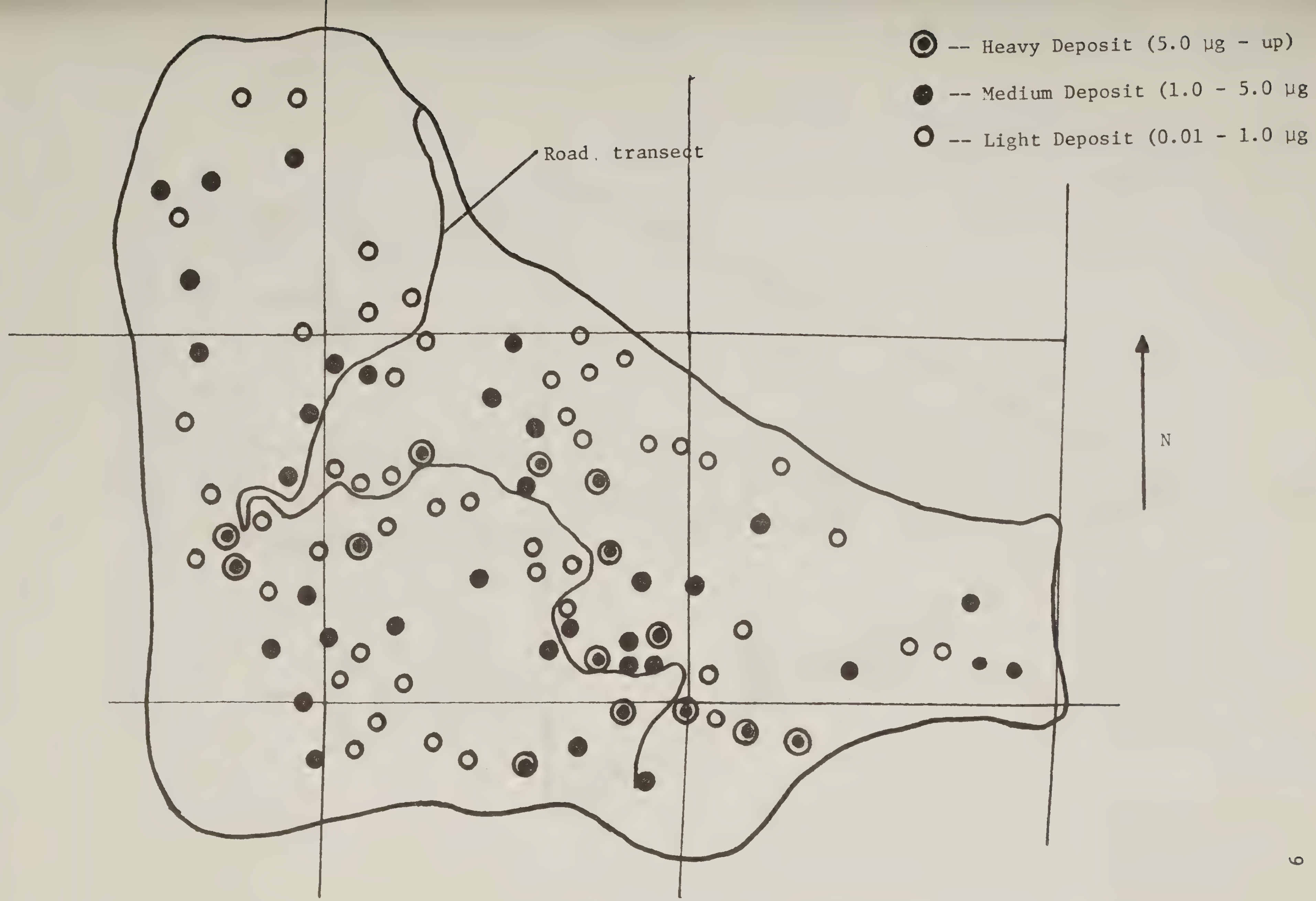

Figure 1.--Fluorescent tracer experimental area. (The sample trees are marked to indicate deposit coverage.)

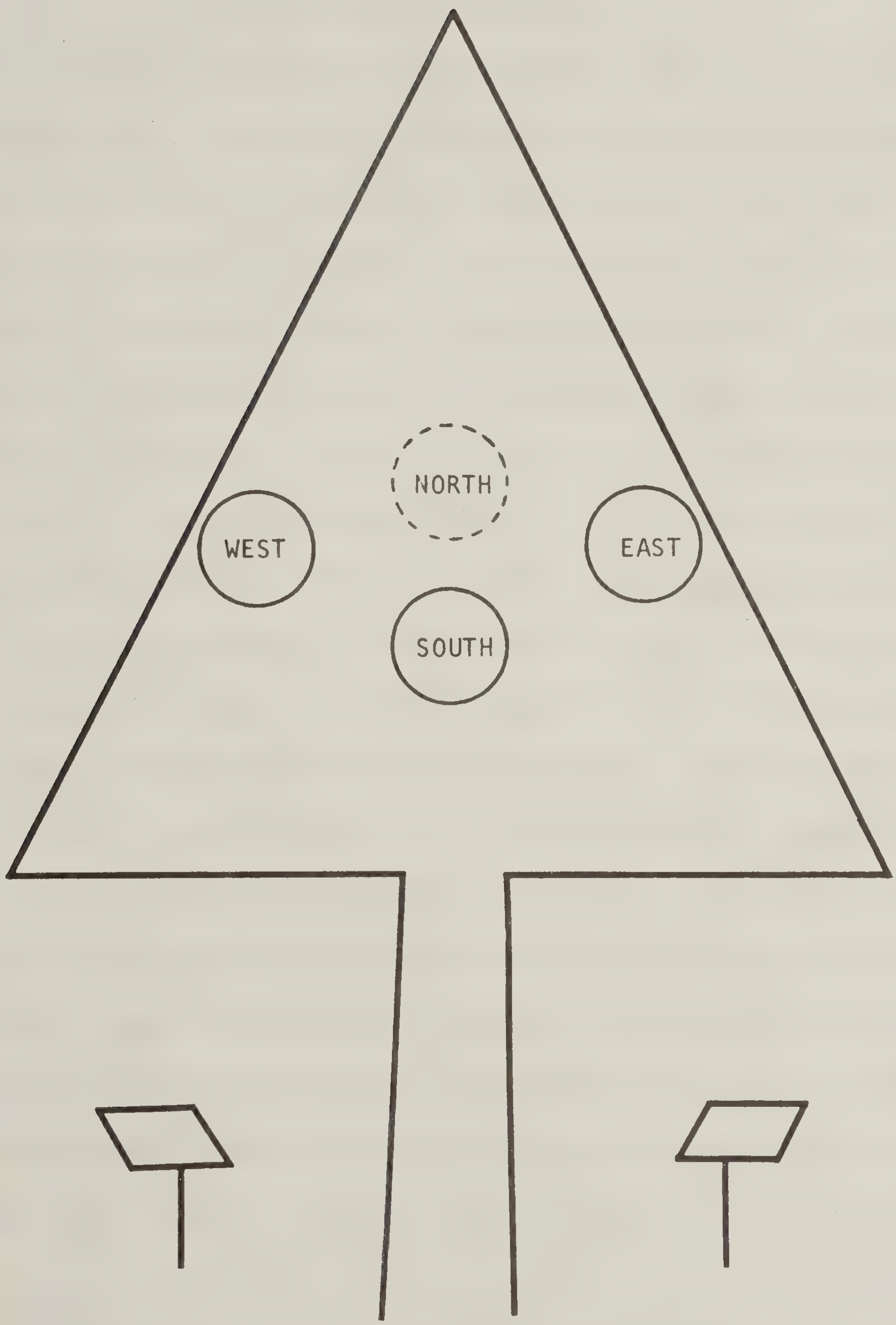

Figure 2.--Position of foliage samples within the tree crown and aluminum plates used for deposit assessment.

RESULTS AND DISCUSSION

Atomization.--The mass median-diameter[3/] (mmd) was determined by two different observers. The difference between observers was less than one micron. The mean mmd computed by the drop size spectra method was 113.7 microns. The estimated number median diameter[4/] (nmd) was 88 microns. The atomization results are depicted in figure 3 which illustrates the relationship between spray volume, numbers of spray drops, and the drop size. The estimated mmd and nmd could be in error since more than one swath (aircraft pass) could be represented on the cards of the atomization sampling line.

Deposit Assessment.--The fluorescent tracer, Rhodamine B Extra Base, provided a simple qualitative tracer method for determining the spray coverage immediately after spraying. Since the tracer was red in color, the spray drops collected on the white Kromekote cards were very visible to the naked eye. Any spot diameter of 100 microns (45 micron drop diameter) or larger was easily detectable, which meant that about 99 percent of the spray volume deposited on the cards was visually detectable. The deposit data from the white cards and aluminum plates that were placed along the roadway are summarized in Table 1. The data show the high correlation between

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[3/] Mass median diameter (mmd) is the drop diameter that divides the spray volume in half; 50% of the spray volume is below, and 50% of the spray volume is above the mmd.

[4/] Number median diameter (nmd) is the drop diameter that divides the number of spray drops in half; 50% of the number of drops is below, and 50% of the number of drops is above the nmd.

RESULTS AND DISCUSSION

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the number of drops per unit area and the amount of spray deposit.

The spray deposit was also visible on the foliage if the foliage was viewed in a darkroom under the ultraviolet light. Low deposits were not visually detectable on the foliage.

For the quantitative assessment, the deposit was expressed in micrograms (μg) of Zectran per 75 needles for the foliage samples and in gallons per acre for the aluminum plates. The 75 needle sample size proved to yield the most consistant results for the foliage.

The distribution of the spray deposit in the experimental area was quite variable (Tables 1-3 and Appendix B). The deposit on the road samples (block transect) ranged from 0.002 to 0.508 gpa, with a mean value of 0.164 ± 0.008[5/]. The inter-tree deposit on the foliage ranged from 0.012 to 16.10 μg Zectran per 75 needles with a mean of 2.623 ± 0.621. The deposit in the open from the ground level sampling stations (12 extra trees) ranged from 0.0064 to 0.2094 gpa with a mean value of 0.084 ± 0.012.

The fact that the mean deposit of these 12 sampling stations was lower than the mean from the road samples (block transect) can be explained by considering the screening effect of the trees that were near the 12 open-ground level stations (usually within 2 tree heights). The screening effect would reduce the deposit reaching the ground level (Maksymiuk, 1963a).

5/ Standard error of the mean is given at the 5 percent probability level.

The intra-tree spray deposit variation is summarized in Table 2. The data show that, on the average, the north side of the tree crowns had about twice the spray deposit as the south side. An analysis of variance showed that the directional dependence of the deposit was significant at the 1 percent probability level. The higher mean deposit on the north side of the tree crowns can be attributed to the general air mass movement from the north. The data in Appendix B show that a 20-fold variation in deposit within a single tree depending upon the directional sample was frequently encountered. These results show the importance of sampling the trees at the four cardinal directions.

The data for the spray deposited at the ground level, under the trees, and in the open, are shown in Table 3. Analysis of the difference of the mean deposit values for the ground level samples show that the difference was only significant at the 10 percent probability level. Although these results were only marginally statistically significant, it is interesting to compare the results with regard to the amount of spray reaching the ground level. The mean difference in deposit between the ground level samples shows that about 54 percent of the spray filtered through the tree canopy. No attempt was made to determine the effect of drop size on the amount of spray that filtered through the tree canopy.

Although no actual drift assessments were carried out, an extrapolation of the existing data (especially the areas of low deposit) showed that the fluorometric method would be sensitive enough to determine drift residues. If aluminum plates would be used as the sampling surface, only 0.005 μg (about 0.0002 gpa) of fluorescent tracer would have to be deposited for the detection of the drift.

Correlation of Spray Deposit and Budworm Mortality.--The pre- and post-spray spruce budworm population densities for Service Flats (test block) and Free Use (control block) are given in Table 4. As can be seen, 4- and 8-day post-spray samples were collected to determine the mortality.

The corrected percent spruce budworm mortality for all the treated blocks are shown in Table 5. The North Meadow Creek and Cougar Creek blocks can be considered as treated controls for the "Rhodamine block" showing that the addition of Rhodamine B Extra Base to the spray formulation had essentially no effect on the budworm mortality. All budworm population and mortality data were supplied by the Insect and Disease Control Branch of Region 1.

When the deposit and the percent of spruce budworm mortality were considered on a tree-by-tree basis, there was a low correlation between the spray deposit and the insect mortality. This result is not surprising when the variations in tree crown deposit and in the larval mortality are taken into account. In an effort to minimize the effects of such variations the sample trees were grouped into six groups according to the mean spray deposit recovered from the trees. A plot of the mean deposit (in logs) vs. the mean mortality

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(in probits) of the respective groups showed a very good correlation between the budworm mortality and the deposit (fig. 4).

It must be emphasized that the data were grouped only in an effort to obtain some relation between the insect mortality and the amount of deposit for the field experiment. Since there were significant variations in the spray deposit within the individual tree crowns, and since the mortality samples were not necessarily collected from the same parts of the tree as the deposit samples, the grouping of the data seemed to be the most plausible method of analysis for the existing data. Research on the experimental design is needed if correlation between mortalities and deposits are to be performed with any consistancy.

Table 1.--Amount of spray deposit recovered from the aluminum plates and the number of spray drops determined on white Kromekote cards along the plot transect (road).

Sampling station no.[a]	Deposit (gpa)	Number of spray drops per sq. cm.	Sampling station no.[a]	Deposit (gpa)	Number of spray drops per sq. cm.
1	.404	52.2	19	.010	5.8
2	.035	8.8	20	.069	12.8
3	.094	15.8	21	.050	10.5
4	.173	25.0	22	.054	11.0
5	.476	60.8	23	.442	56.8
6	.120	18.8	24	.098	16.2
7	.118	18.5	25	.126	19.5
8	.190	27.0	26	.226	31.2
9	.236	32.5	27	.387	50.2
10	.508	64.5	28	.046	10.0
11	.044	9.8	29	.116	18.2
12	.004	3.5	30	.198	28.0
13	.002	0.8	31	.370	48.2
14	.304	40.5	32	.177	25.5
15	.002	0.2	33	.099	16.2
16	.004	3.5	34	.222	30.8
17	.042	9.5	35	.321	42.5
18	.039	9.2	36	.088	15.0
			Mean	0.164 $\pm$ 0.045	23.6 $\pm$ 5.9[b]

a/ These stations were located at intervals of 0.1 mile.

b/ Standard error of the mean is at the 5 percent probability level.

Table 2.--Summary of the estimated amount of Zectran recovered from the foliage samples obtained from the four cardinal directions of the tree crowns.

Direction	Number of samples	Mean deposit (µg/75 needles)	Deposit range (µg/75 needles)
North	96	3.3140 ± 0.8573[a]	0.0 - 17.5771
East	96	2.9062 ± 1.0511	0.0 - 38.4551
South	96	1.8944 ± 0.6201	0.0 - 16.3894
West	96	2.3836 ± 0.7415	0.0 - 21.9750

[a] Standard error of the mean is at the 5 percent probability level.

Table 3.--Summary of the spray deposit recovered at the ground level under the tree canopies and in the adjacent openings.

Sampling station no.	Under the tree canopy		In the open	
	gpa	mean no. of drops per sq. cm.	gpa	mean no. of drops per sq. cm.
1	.030	9.8	.209	21.2
2	.010	6.8	.027	14.8
3	.007	3.0	.006	1.2
4	.006	1.0	.010	6.5
5	.005	4.0	.043	6.2
6	.252	25.8	.089	12.5
7	.030	14.2	.175	42.8
8	.106	8.5	.128	37.5
9	.038	5.8	.082	27.5
10	.011	5.2	.012	3.2
11	.024	4.0	.143	13.2
12	.028	7.2	.080	11.8
Mean	.045 ± .013[a]	7.9 ± 4.0	.084 ± .012	16.5 ± 10.5

a/ Standard error of the mean at the 5% probability level.

Table 4.--Western spruce budworm population densities, pre- and post-spray, Nezperce N. F., 1971[a/].

Area	Treatment	Tree species	Number of larvae/100 buds, $\pm$ 1 S.E.		
			pre-spray	4 day post-spray	8 day post-spray
Service Flats	treated	GF	4.32 ± 0.33	2.83 ± 0.25	1.90 ± 0.26
		DF	6.21 ± 0.83	3.96 ± 0.46	2.56 ± 0.46
Free Use	untreated	GF	7.55 ± 0.79	7.46 ± 0.82	5.86 ± 0.63
	control	DF	9.47 ± 0.92	8.51 ± 0.72	7.48 ± 0.58

a/ Data provided by Region 1.

Table 5.--Corrected percent mortality, western spruce budworm pilot test, Nezperce N. F., 1971[a].

Area	Treatment	Tree species	Corrected percent mortality due to Zectran[b]	
			4-day	8-day
Service Flats	Rhodamine +	GF	33.58	43.46
	Zectran	DF	28.96	47.78
North Meadow	Zectran	GF	51.09	53.77
	(treated control)	DF	65.22	68.08
Cougar Creek	Zectran	GF	47.96	43.41
	(treated control)	DF	36.89	28.42

a/ Data provided by Region 1.

b/ Corrected % mortality derived as follows:

$$100 \left(1.0 - \frac{\text{survival treated}}{\text{survival control}}\right)$$

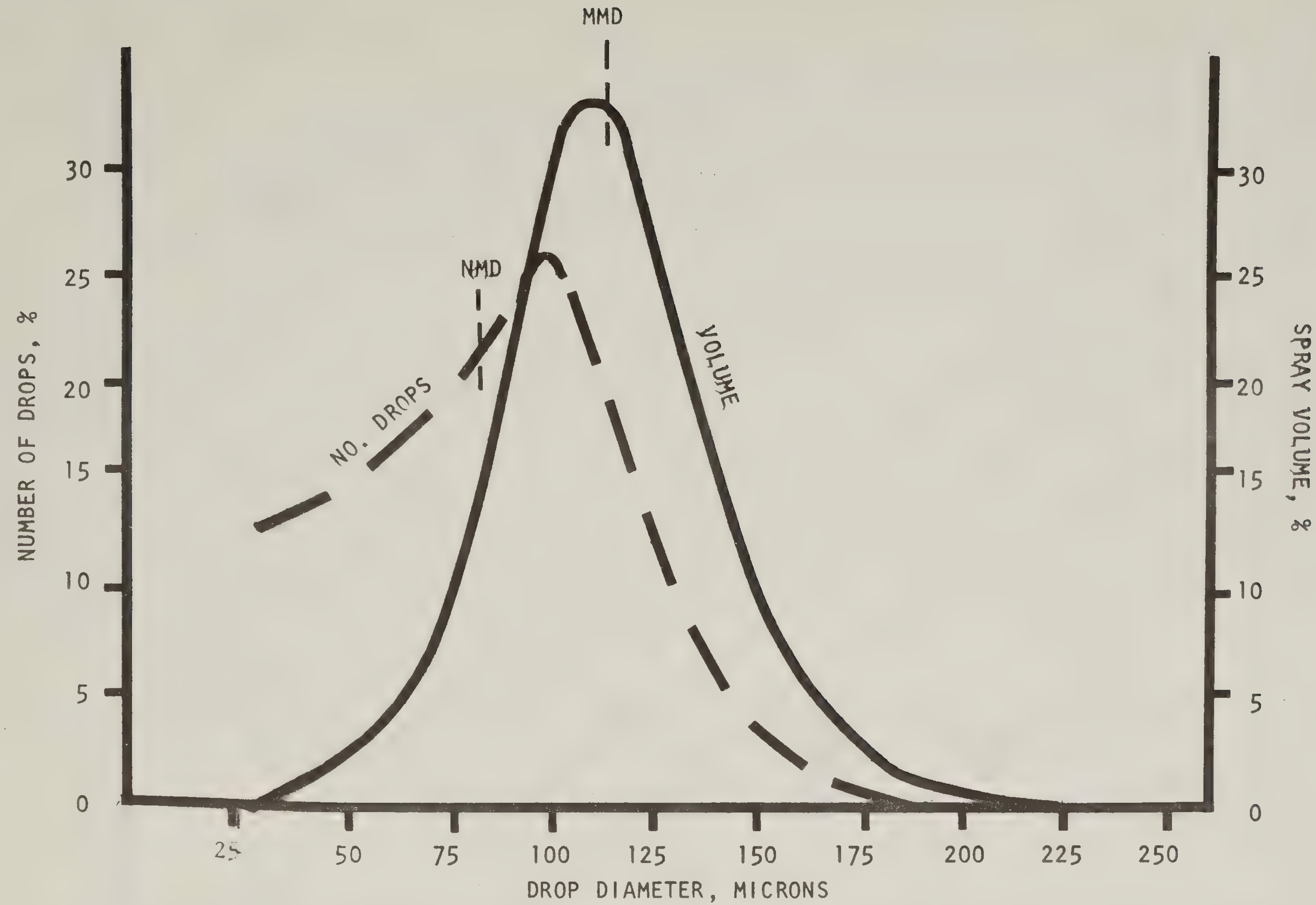

Figure --Relationship between drop diameter, number of drops, and spray volume.

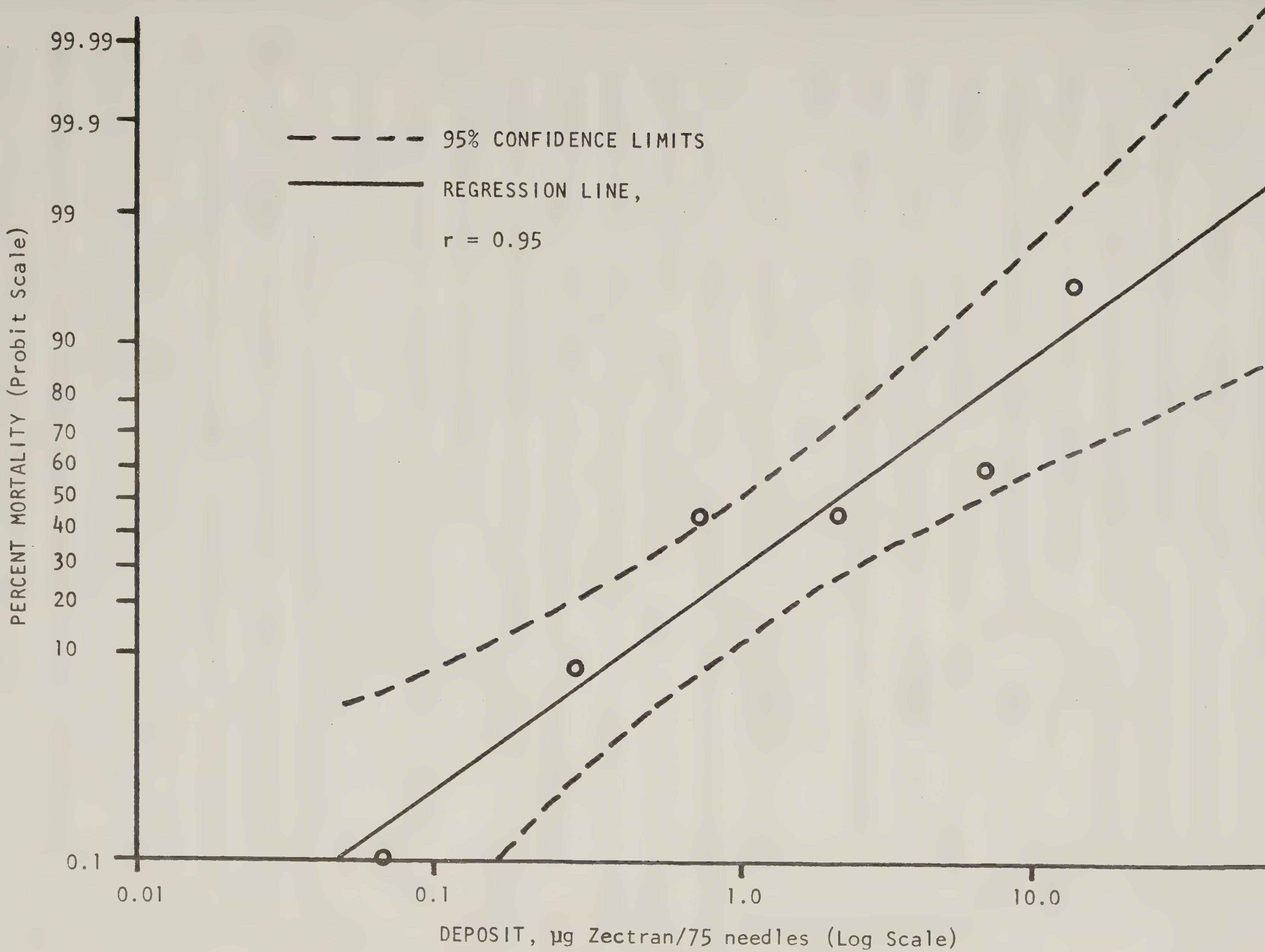

Figure 4.--Relationship between spruce budworm mortality and Zectran deposit.

CONCLUSIONS AND RECOMMENDATIONS

The fluorescent tracer, Rhodamine B Extra Base, and the analytical fluorometric methods seemed to provide an economic, fast, and reliable assessment of the spray deposit. The cost of the Rhodamine was about eight cents per total gallon of spray. It should be emphasized that this method yields only an indirect estimate of the quantity of insecticide. The estimated amount of insecticide is based on the concentration of the fluorescent tracer. However, the validity of such estimates has been demonstrated for agricultural sprays.

There was a wide variation in the deposit coverage both within and between the individual trees. Likewise, there was a wide variation in the spray deposit reaching the ground level, both under the tree canopies and in the open. Since there was such a wide variation both in the deposit and in the larval mortalities, a high correlation between the spray deposit and the spruce budworm mortality could only be achieved by grouping the data.

Based on the results of this field experiment the following is recommended:

1. To develop standards for estimating spray deposits on white Kromekote cards for fluorescent tracer(s). This method will provide a rapid evaluation of the deposit distribution for field operations.

2. To refine and standardize analytical procedures for the quantitative assessment of spray deposits on the foliage and other sampling surfaces. This would include such investigations as the extent of fading of the tracers under variable field conditions.

CONCLUSIONS AND RECOMMENDATIONS

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3. To improve the spray deposit and insect sampling design to provide the best evaluation of the correlation between the deposit and insect mortality.

Realization of these recommendations is necessary for developing safe and effective aerial application of pesticides.

REFERENCES CITED

Davis, J. M., and K. R. Elliott.

1953. A rapid method of estimating aerial spray deposits. J. Econ. Entomol. 46(4): 696-698.

____________ W. E. Waters, D. A. Isler, R. Martineau, and W. Marsh.

1956. Experimental airplane spraying for spruce budworm control. J. Econ. Entomol. 49(3): 338-341.

Himel, C. M., and A. D. Moore.

1967. Spruce budworm mortality as a function of aerial spray droplet size. Science 156(3779): 1250.

____________ L. Vaughn, R. P. Miskus, and A. D. Moore.

1965. A new method for spray deposit assessment. USDA Forest Serv. Res. Note PSW-87, 10 pp.

Honing, F. W.

1968. Spruce budworm Zectran pilot control test. Bitterroot National Forest. U.S. Forest Serv., Northern Region, Div. of State & Private Forest., Report, 13 pp.

Isler, D. A.

1962. Methods used in forest spraying for evaluation of coverage and drop size. Presentation at 1962 Annual Meeting, Amer. Soc. Agr. Eng., 9 pp.

Maksymiuk, Bohdan.

1959. Improved holders for spray deposit assessment cards. J. Econ. Entomol. 52(5): 1029-1030.

____

1963a. Screening effect of the nearest tree on aerial spray deposit recovered at ground level. J. Forest. 61(2): 143, 144.

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1963b. Spray deposit on oil-sensitive cards and spruce budworm mortality. J. Econ. Entomol. 56(4): 465-467.

____

1964. The drop size spectra method for estimating mass median diameter of aerial sprays. USDA, Forest Serv. Res. Pap. WO-1, 9 pp.

Yates, W. E., and N. B. Akesson.

1963. Fluorescent tracers for quantitative microresidue analysis. Trans. Amer. Soc. Agr. Eng. 6(2): 104-107, 114.

APPENDIX A

Required dose of Zectran for LD-50 using fourth and fifth instar larvae of Choristoneura occidentalis (Corvallis data).

Registered Zectran formulation[a]	Dose for LD-50[b]	
	micrograms per larva	micrograms per gram of body weight
With 0.1% Rhodamine	0.01	0.29
Without Rhodamine	0.01	0.29

[a] 0.15 lb. of Zectran per one gallon of finished spray (1 part of FS-15 plus 9 parts of deodorized Kerosene).

[b] 7 days mortality corrected for natural mortality in untreated controls.

APPENDIX B

ZECTRAN SPRAY DEPOSIT (µg/75 NEEDLES) RECOVERED FROM THE FOLIAGE[a/]

Tree No.	Tree Species	Average Directional Deposit				Average Deposit Per Tree
		East	West	North	South	
601	DF	6.6777	.4701	6.2296	1.1190	3.62
602	DF	2.6446	.5583	3.2274	2.6985	2.28
603	GF	.1518	.2301	0	.0440	.11
604	DF	2.2112	3.4821	3.7490	10.5932	5.01
605	DF	8.3796	13.0714	5.2452	.6954	6.85
606	DF	10.3239	7.2776	5.0934	.6954	5.85
607	DF	3.3351	4.6673	1.0235	16.3894	6.35
608	DF	2.1475	1.9247	1.5108	1.4692	1.76
609	DF	3.0633	.9207	1.7435	4.2755	2.50
610	DF	13.5807	.9207	14.1782	1.0505	7.43
611	GF	5.3358	.1518	8.4139	.1959	3.52
612	GF	.8766	.2914	3.8984	0	1.27
613	GF	1.9173	1.0798	1.4692	.8962	1.40
614	GF	2.1353	11.6119	15.3463	4.6183	8.43
615	DF	8.1127	3.1001	8.1739	.5191	4.98
616	GF	2.9629	1.0872	3.1344	.2497	1.86
617	DF	10.6520	9.6358	3.2078	10.8626	8.59
618	DF	.8546	1.1362	.5289	.9354	0.86
619	GF	5.4558	2.1353	6.6508	1.0701	3.83
620	DF	8.0808	9.0701	15.1651	11.2324	10.89
621	GF	.2791	.1763	1.117	0	0.39
622	DF	.2203	.4824	.5460	.5387	0.45

Tree No.	Tree Species	Average Directional Deposit				Average Deposit Per Tree
		East	West	North	South	
623	DF	1.0456	1.2562	1.1607	.5460	1.00
624	DF	1.7141	1.5525	1.6161	1.0456	1.48
625	GF	.0342	.0244	.0391	0	0.02
626	DF	.3036	3.3254	.8227	3.3915	1.96
627	DF	2.5467	.8668	3.4184	.2816	1.78
628	GF	.2595	1.8022	2.5442	1.3076	1.48
629	GF	1.7631	1.0652	1.9663	1.0701	1.46
630	DF					
631	DF	25.9763	5.2452	17.5771	6.0092	13.64
632	DF	.3011	.3550	.5142	.3330	0.37
633	DF	.5166	.4701	.7370	.4064	0.53
634	DF	.1224	.5779	.1567	.5877	0.36
635	DF	12.2364	1.4055	7.4539	10.6520	7.94
636	GF	0	.0979	0	.1175	0.05
637	DF	.1518	.1591	.1273	.2056	0.16
638	DF	3.5408	.3771	1.1509	2.3067	1.84
639	DF	.7982	1.3982	1.8708	2.1010	1.54
640	GF	2.7034	.9648	.1959	1.3664	1.31
641	DF	3.6755	5.7814	9.1877	1.5476	5.05
642	DF	.3403	1.4888	1.6651	1.0039	1.22
643	DF	3.8984	3.7808	3.5164	8.7395	4.98
644	DF	1.0896	.1126	.3036	.2032	0.18
645	DF	1.1705	.5460	1.3419	1.1411	1.05
646	DF	1.9883	.7787	1.5745	.7517	1.27
647	GF	3.5310	.4652	1.8292	.2914	1.53

Tree No.	Tree Species	Average Directional Deposit East	West	North	South	Average Deposit Per Tree
648	GF	.1101	.4603	.0342	.9550	0.39
649	DF	1.0407	.6513	.4554	1.1949	0.84
650	DF	1.9614	.1910	.7199	.1836	0.76
651	GF	.2742	.2473	0	.0122	0.13
652	DF	1.3100	1.5867	2.1842	1.0578	1.53
653	GF	.9109	.0024	.0122	.4824	0.35
654	DF	1.4692	.5093	5.9896	1.9932	2.49
655	GF	2.7181	1.8169	3.0609	.8521	2.11
656	GF	1.0137	.3232	1.1117	.1836	0.66
657	DF	1.3076	1.4863	.3869	.7003	0.97
658	DF	2.3605	6.5871	8.5902	3.8616	5.35
659	GF	1.5133	.5191	.3134	.8864	0.80
660	GF	.2791	1.4031	1.0015	.6513	0.83
661	GF	5.7055	21.9750	14.8981	1.1386	10.93
662	GF	0	1.4031	9.8782	.3011	2.89
663						
664						
665	GF	7.2189	.4285	.6317	.2252	2.13
666	GF	1.3859	2.7817	9.9370	.1371	3.56
667						
668	GF	.0293	.3477	.2914	0	0.17
669	GF	.5387	.3624	.2693	.3330	0.37
670	GF	6.9495	6.5234	5.8427	7.8457	6.79
671	GF	1.1166	.2105	.4211	.2938	0.51

Tree No.	Tree Species	Average Directional Deposit East	West	North	South	Average Deposit Per Tree
672	DF	.2693	13.5954	.2056	10.3239	6.10
673	GF	.7052	.5974	.6415	.3771	0.58
674	GF	.0342	.2644	.6513	.0563	0.25
675	GF	2.9678	5.2158	11.5507	1.3296	5.25
676	DF	2.3850	6.8271	1.6920	.6219	2.88
677	DF	1.5427	.3869	3.0168	1.1827	1.53
678	DF	.6219	1.0872	2.5613	1.6504	1.48
679	GF	.3526	.7052	.4407	.8839	0.60
680	GF	.2742	1.7337	.5191	1.2439	0.94
681	GF	1.6798	6.0826	3.0584	1.9247	3.18
682	GF	.2497	0	.5044	.2154	0.24
683	GF	.8350	.3232	.8423	0	0.50
684	GF	.0391	.0293	.1028	.0685	0.06
685	GF	.2032	1.8022	6.2002	2.9737	2.80
686	GF	1.6945	.3477	.1420	1.9736	1.04
687	DF	.3109	.5093	2.0618	1.0382	0.98
688	GF	.2595	.0244	.4824	.1763	0.24
689	GF	7.0670	.4775	7.1870	.1224	3.71
690	DF	.5191	2.2332	2.7621	.4162	1.48
691	DF	2.6862	13.1326	11.0707	1.7239	7.15
692	DF	1.2464	.9795	1.1215	.7370	1.02
693	DF	.4407	1.6847	2.5148	2.8699	1.88
694	DF	38.4551	7.3952	16.8669	1.6896	16.10
695	GF	0	.0489	0	0	0.01
696	GF	1.2537	.6195	1.1509	.0979	0.78

Tree No.	Tree Species	Average Directional Deposit				Average Deposit Per Tree
		East	West	North	South	
697	GF	.0661	.1003	.1885	0	0.09
698	GF	.5240	.9892	1.2194	0	0.68
699	DF	1.2194	2.6691	1.9026	.8276	1.66
700	DF	2.7768	1.7704	1.0456	8.5020	3.52

[a] Each directional deposit value is an average of two subsamples.

APPENDIX C

White Kromekote card showing spray deposit of the registered Zectran formulation using Rhodamine B Extra Base fluorescent dye tracer for the spray deposit assessment (field experiment, Idaho, 1971).